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Centre de coopération internationale en recherche agronomique pour le development

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Montpellier, France

Differential effects of day and night temperature on leaf elongation and determination of apparent base temperature for contrasted genotypes

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Estela Pasuquin, Bancha Wiangsamut
Cool rice for a warmer world, 28 March 2007, Wuhan, China

Temperature effect on grain yield

- **Detrimental effect of elevated temperature on grain yield in rice (Peng et al., 2004; Sheehy et al., 2005)**
- **Crop response to temperature and its magnitude differed with regard to:**
  - the range in climate conditions and associated correlation between climate factors, particularly radiation, day and night temperature
  - the approach for analysis: correlations or models

⇒ **Confounding effects make it difficult to quantify the differential effects of radiation, day and night temperature on a highly integrated variable like grain yield which implies a long time scale approach**

⇒ **Analyzing the day and night temperature effect on underlying straight forward processes driving grain yield is a key step**

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Response of plant growth and development to temperature: the thermal time concept

- **Calculation of thermal time in rice is reported in the literature with a range of temperature coefficients, with base temperature varying from 8 to 14C depending on**
  - the genotype,
  - the growing conditions (field and controlled),
  - the process under consideration (leaf emergence, time to flowering),
  - the location of temperature measurement (air or tissue temperature),
  - the fitted mathematical function (linear and non linear functions)

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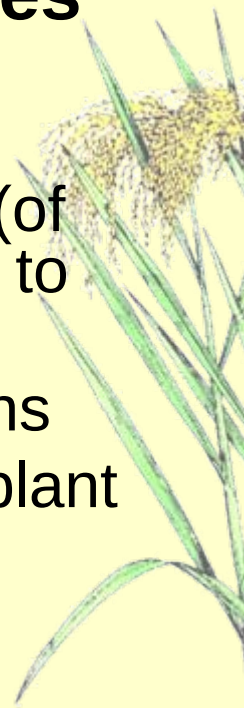
Response of plant growth and development to temperature: the thermal time concept

- **Calculation of thermal time, however, implies that:**
  - distinct processes like development rate (leaf emergence, time to flowering) and elongation rate (of different leaves, of different internodes) are related to temperature with the same parameters
  - these parameters are stable in contrasted conditions
  - the mathematical function used to account for the plant response to temperature is valid in a wide range in conditions



- **The variability between genotypes needs to be addressed**

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Why looking at leaf elongation?

- **Organ elongation (blade, sheath, culm):**
  - is a key underlying process for leaf area production and time to flowering, directly driving grain yield
  - is directly controlled by temperature in favorable growing conditions
- **Measuring visible leaf elongation is a non-destructive technique and then reduces sampling errors**
- **Response of blade, sheath and internode elongation are dependent on the same processes and might be affected by temperature in the same way.**

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Why measuring elongation in controlled conditions?

- Climatic demand (or air dryness or VPD) affects leaf elongation. And daytime temperature is highly correlated with VPD.

  ⇒ It is essential to consider low VPD conditions when comparing differential day and night temperature effects to differentiate the effect of high temperature from that of high VPD.
- Plant response is studied in a wider range in temperature conditions

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Why measuring elongation of leaves 6 and 9?

- **Elongation rate of leaves 6 and 9 are contrasted (LER increases with leaf position on the stem until about leaf 10)**

- **Elongation of leaf 6 started after seedling establishment (transplanting was done at 3-leaf stage when leaf 4 was expected to emerge and leaf 5 was already growing)**

- **Elongation of leaf 9 finished before the start in culm elongation (so that non-destructive observations accounted for leaf elongation only. Non-destructive observations of elongation of leaves from upper positions was the sum of leaf and internode elongation)**

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How was elongation measured?

A fixed horizontal ruler was placed in contact to the leaf blade

Elongation of leaf only was measured (the culm was not yet growing)

Actual leaf length was measured from the ruler to the tip

Measurements were done daily at 6am and 6pm

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Experimental set up

High-yielding elite lines	IR8	I0
	IR72	I1
	IR64	I2
High-yielding hybrids	IR75217H	H1
	SL-8	H3
	IR78386H	H5
	Bigante	H9
New plant types	NPT 2nd	N1
	NPT 1st	N7
Cold tolerant genotypes	Imbonggo	I31
	Biniggon	I32
	SHZ-2	I33
	IRKR22	I35
Drought tolerant genotypes	Apo	I21
	Vandana	I22
	IR77843	H11

Leaf elongation of 16 contrasted genotypes was measured

Sowing dates were organized by a regular time interval so that leaves 6 and 9 of distinct sets of plants were growing simultaneously

Temperature conditions were modified for each set of leaves 6 and 9 growing together

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Why measuring micro-climate conditions?

- **It is essential to measure micro-climate data to access to the real conditions affecting plants and to deal with confounding factors:**
  - With regard to the vegetative phase, apical meristem is the site where most growth processes are initiated and occur. Growth processes are highly controlled by temperature. In flooded rice, meristem temperature is equivalent to water temperature before PI

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Experimental set up

Microclimate data were measured continuously and stored every 30 minutes

Water temperature was measured in a large set of pots

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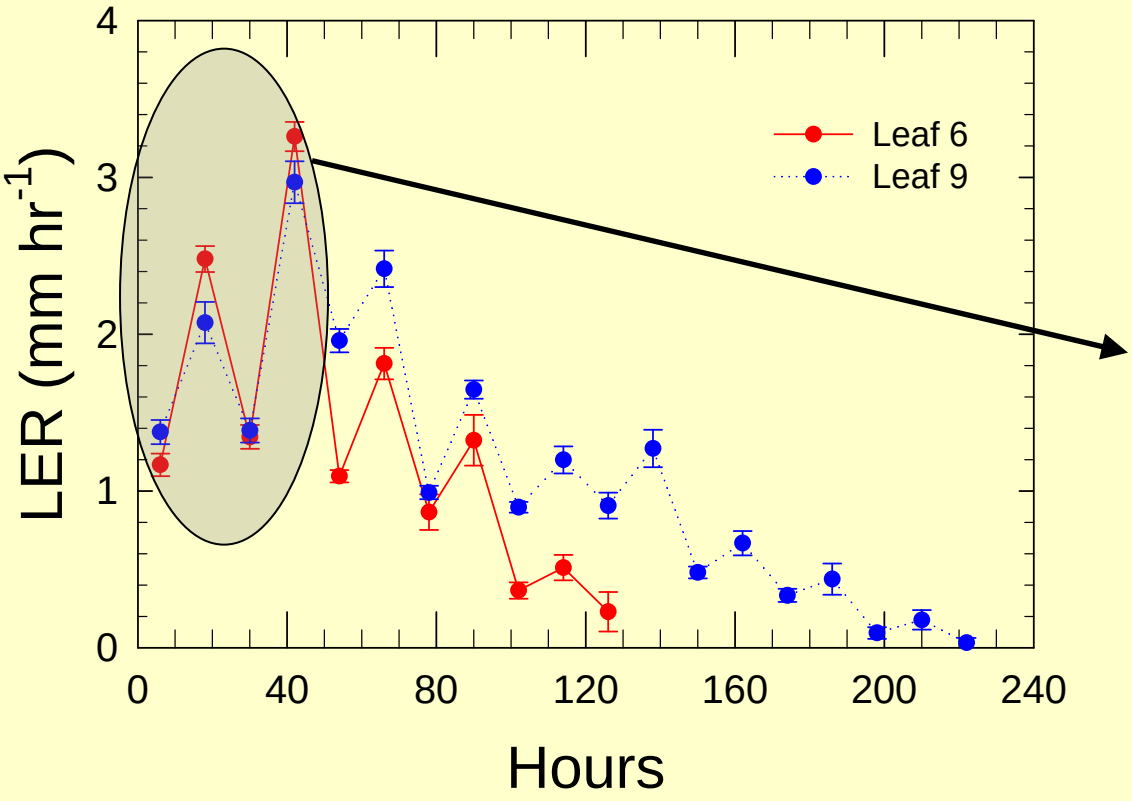
Diurnal variation of LER of leaves 6 and 9 in the greenhouse with time from transplanting



Short period during which LER is maximal before reduction in LER due to leaf age

LER_{max} values corresponded to data collected during the first 2 days after leaf emergence only

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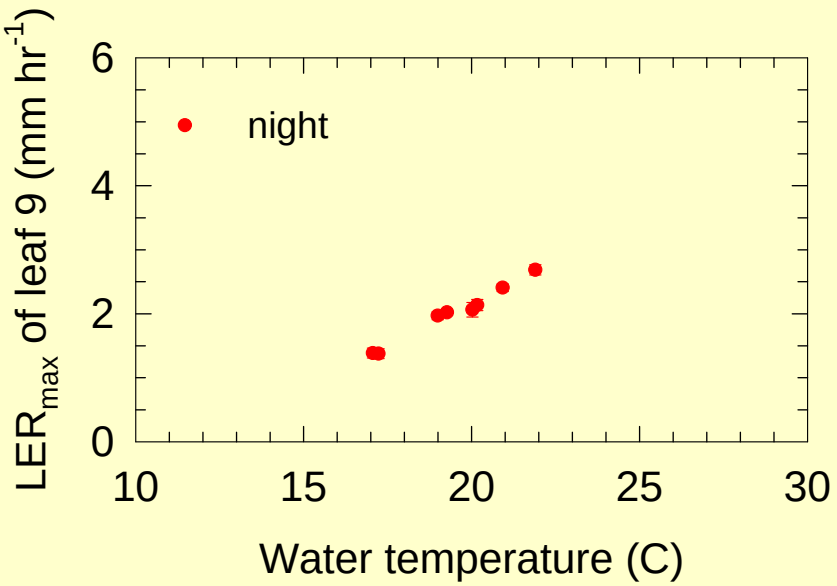
Response of LER_{max} of leaf 9 to water temperature

Variety I2 (IR64)



Increase in LER_{max} in the range of water temperature from 17 to 22 C for night time periods

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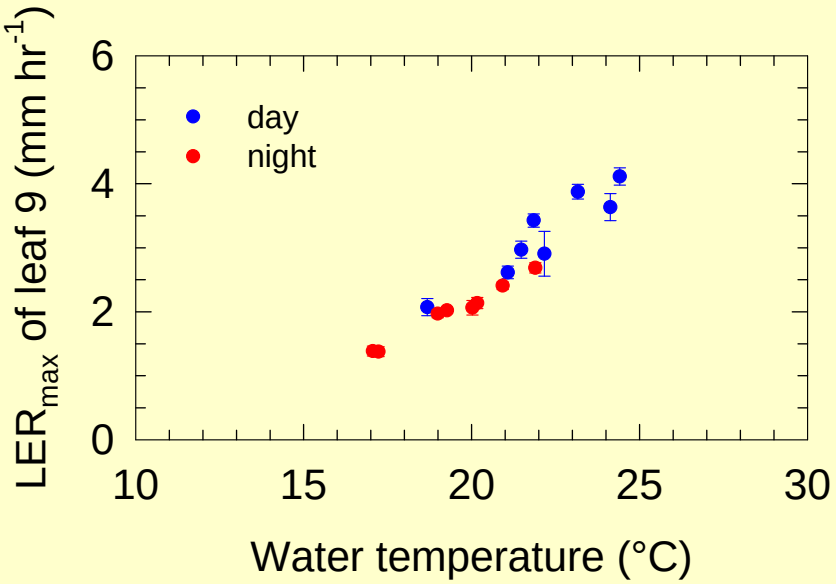
Response of LER_{max} of leaf 9 to water temperature

Variety I2 (IR64)



Average daytime air VPD values were below 0.5 kPa

Increase in LER_{max} in the range of water temperature from 17 to 25 C

Similarity of the response for night and day time periods

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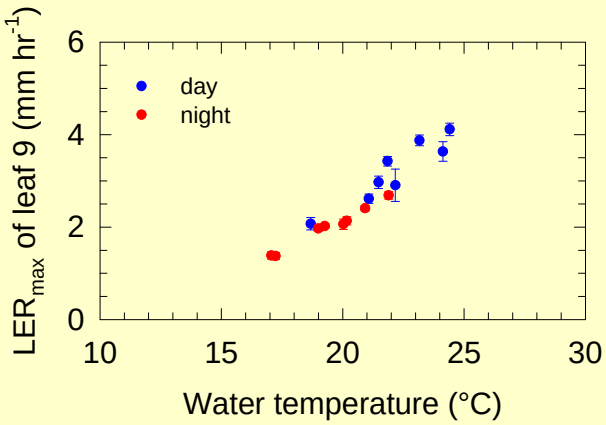
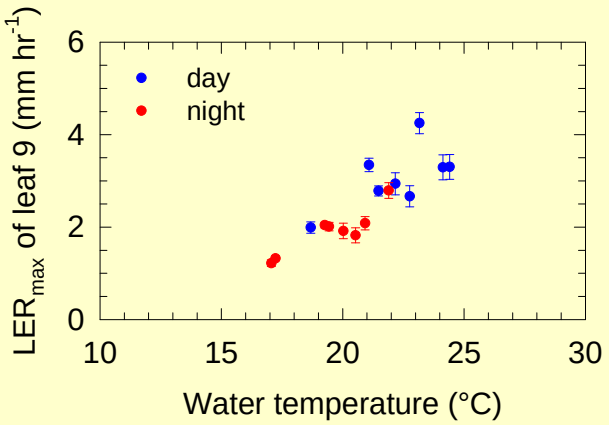
Response of LER_{max} of leaf 9 to water temperature

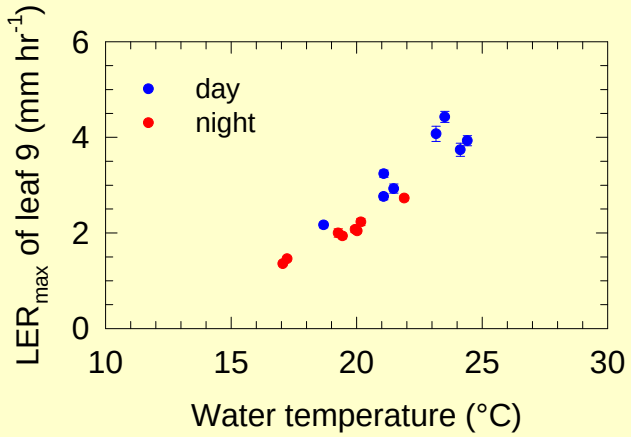
IR64



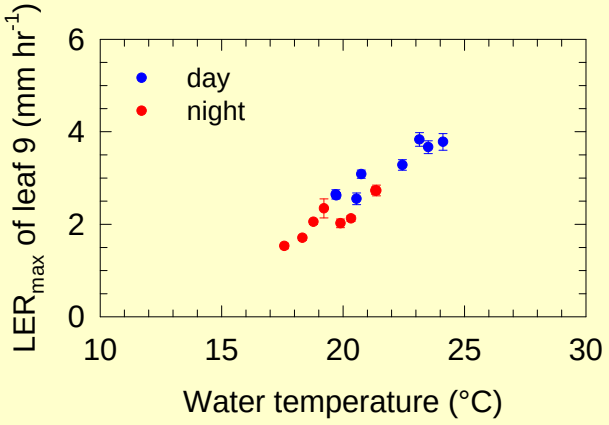
Hybrid rice



Cold tolerant



Drought tolerant



Common response for contrasted genotypes

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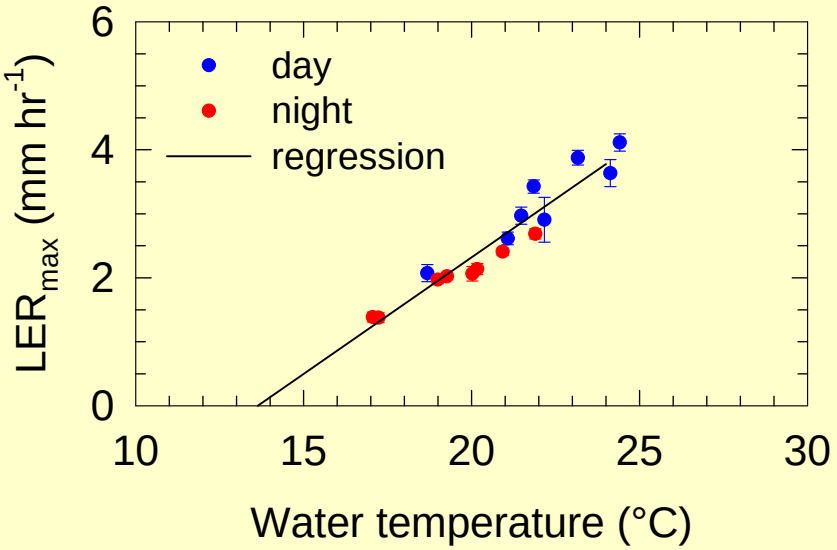
Response of LER_{max} of leaf 9 to water temperature

Variety I2 (IR64)



In the conditions from 17 to 25 °C, a linear response can be considered.
Some extra data at lower temperature will provide great information with regard to the shape of the response and its validity in a large range of conditions.

This linear response is at least valid in the tropics where the night temperature does not go below 20 °C.

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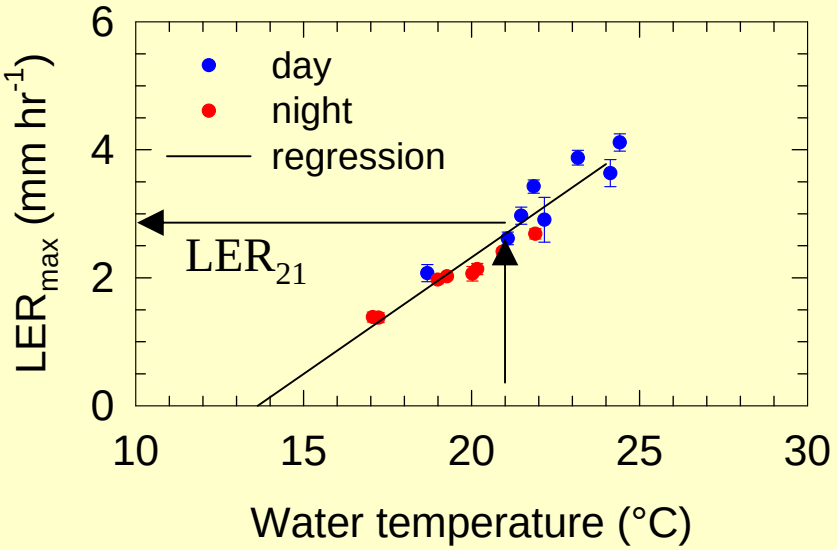
Comparing the temperature response of LER_{max} of 2 distinct leaves with contrasted absolute values

LER_{max} of leaves 6 and 9 were normalized with respect to their corresponding values obtained from the regression line at 21 C

Variety I2 (IR64)



LER_{reg} was then calculated for each LER_{max} of leaf 6 and leaf 9:

$$LER_{reg} = LER_{max} / LER_{21}$$

and plotted against water temperature…

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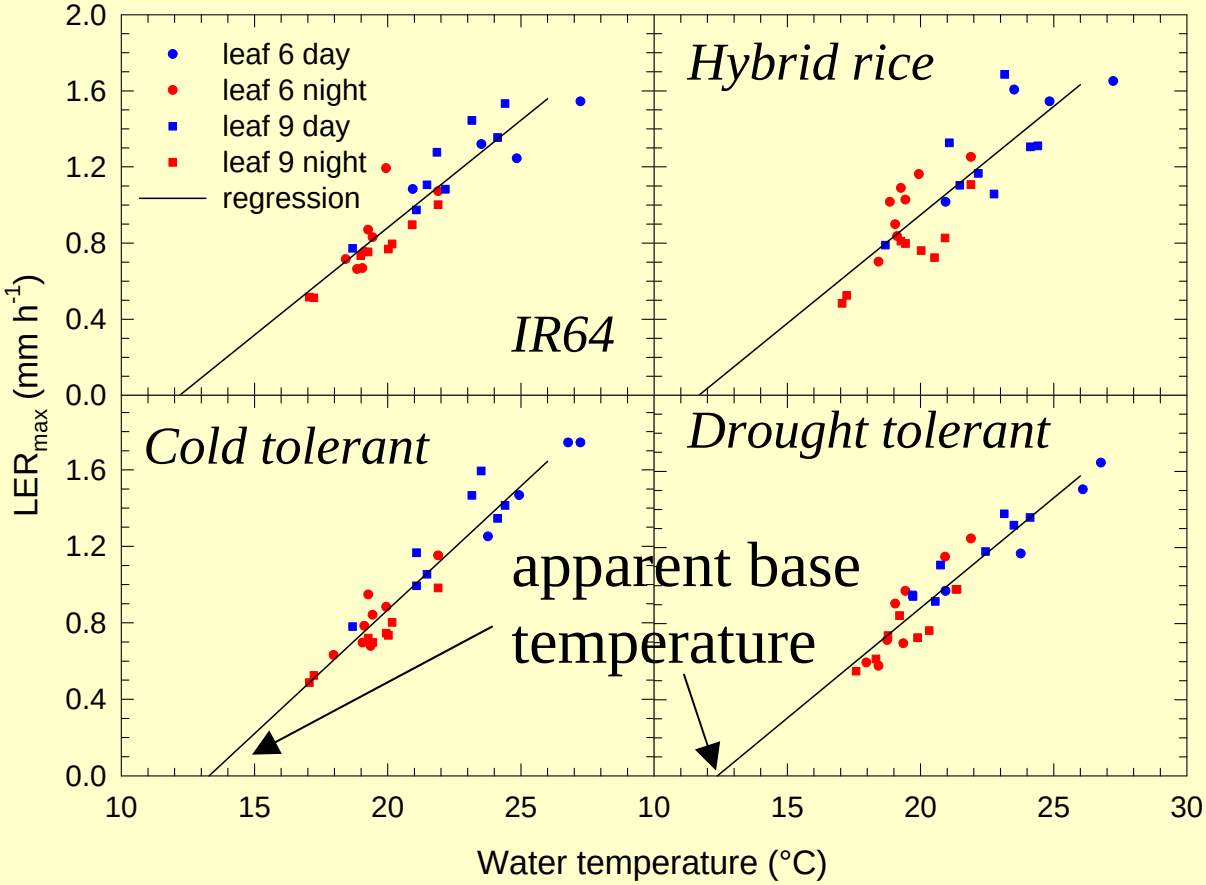
Temperature response of LER_{max} of leaves 6 and 9



For a range of genotypes, normalized slopes and x-intercepts did not differ significantly: - for leaves 6 and 9

- for day and nighttime periods

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Variability of the apparent base temperature for leaf elongation assuming a linear response to temperature

Plant type			r^2	*X-intercept* (°C)
High-yielding elite lines	IR8	I0	0.82	13.56
	IR72	I1	0.57	11.65
	IR64	I2	0.85	12.20
High-yielding hybrids	IR75217H	H1	0.54	10.57
	SL-8	H3	0.52	11.00
	IR78386H	H5	0.73	11.68
	Bigante	H9	0.65	11.24
New plant types	NPT 2nd	N1	0.45	10.41
	NPT 1st	N7	0.74	12.43
Cold tolerant genotypes	Imbonggo	I31	0.66	11.87
	Biniggon	I32	0.59	10.94
	SHZ-2	I33	0.92	13.29
	IRKR22	I35	0.79	12.74
Drought tolerant genotypes	Apo	I21	0.88	12.38
	Vandana	I22	0.65	11.66
	IR77843	H11	0.81	13.03

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Leaf elongation of leaves 6 and 9 measured in the field

Distinct growing periods were considered to get access to a range in temperature conditions : 10 sowing dates from early January to mid-May every 2 weeks to have plants growing during the cooler (January-February) and hotter (April-May) part of the season

16 genotypes as in the phytotron

Similar crop management and data collection

Continuous micro-climate data collection including water temperature and humidity

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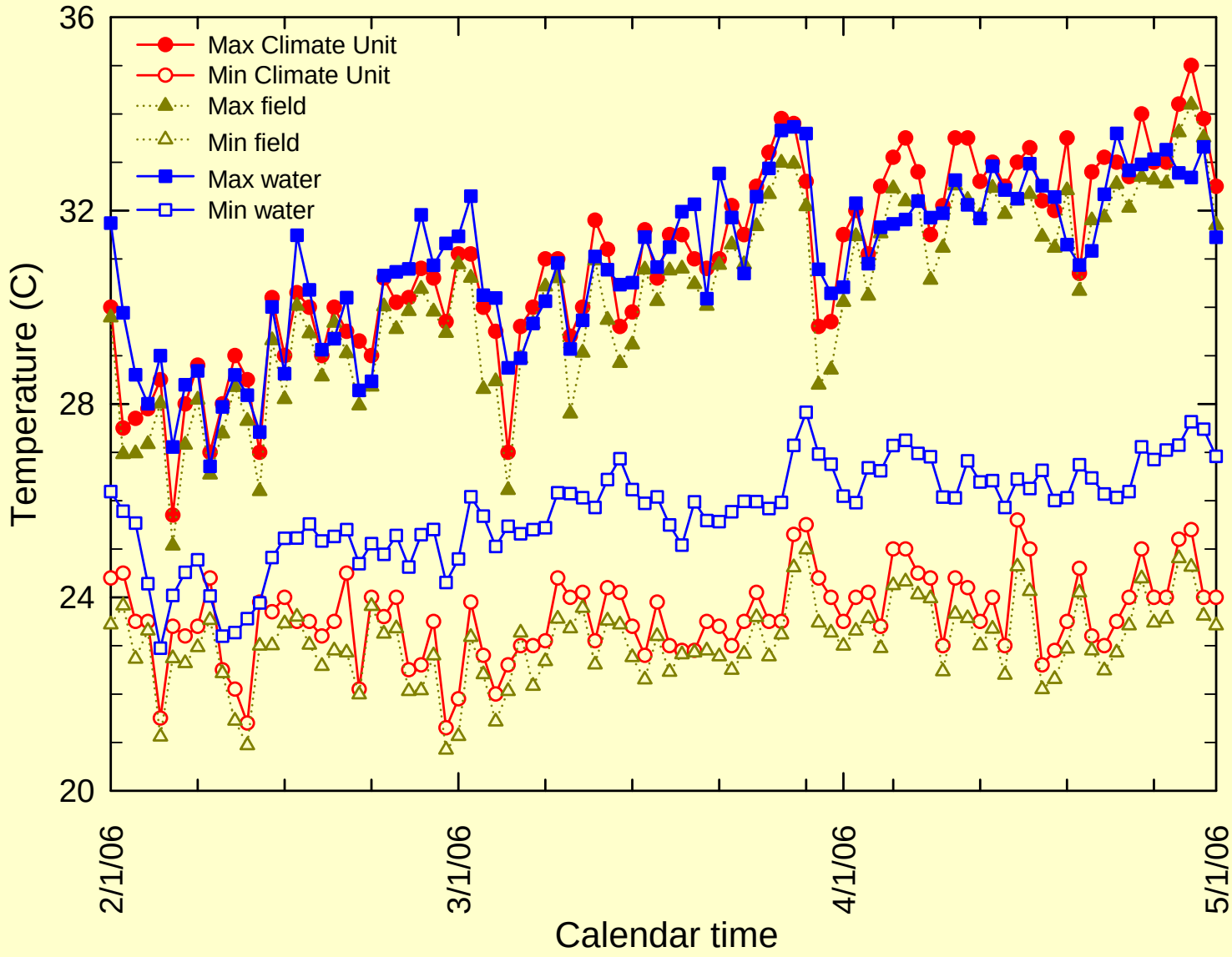
Dealing with temperature in the field: water temperature in irrigated rice at night was 2C higher than air temperature



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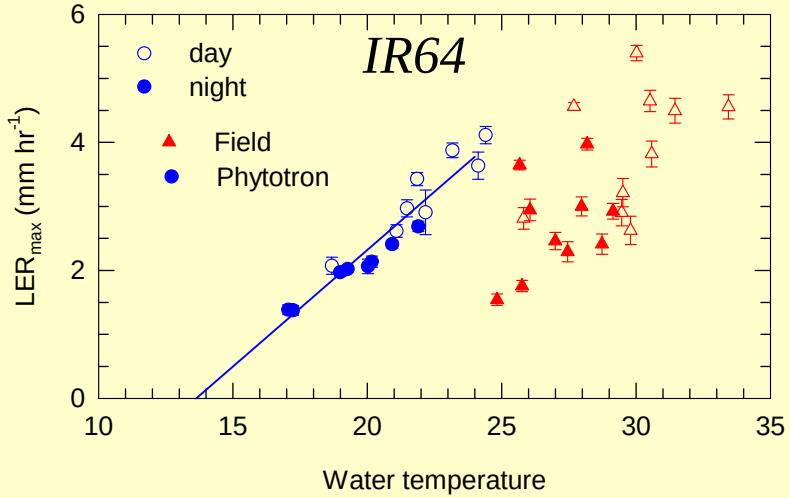
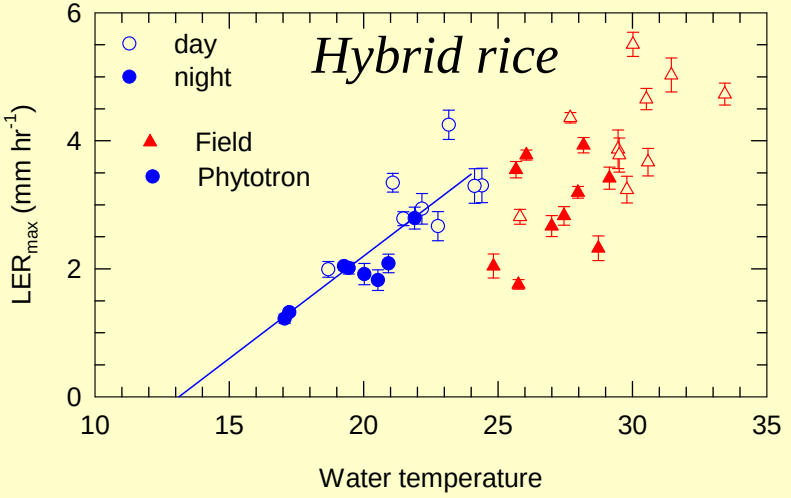
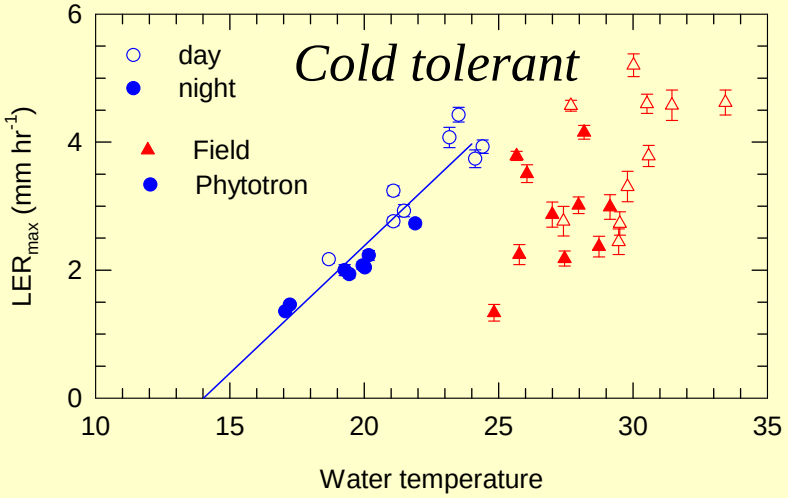
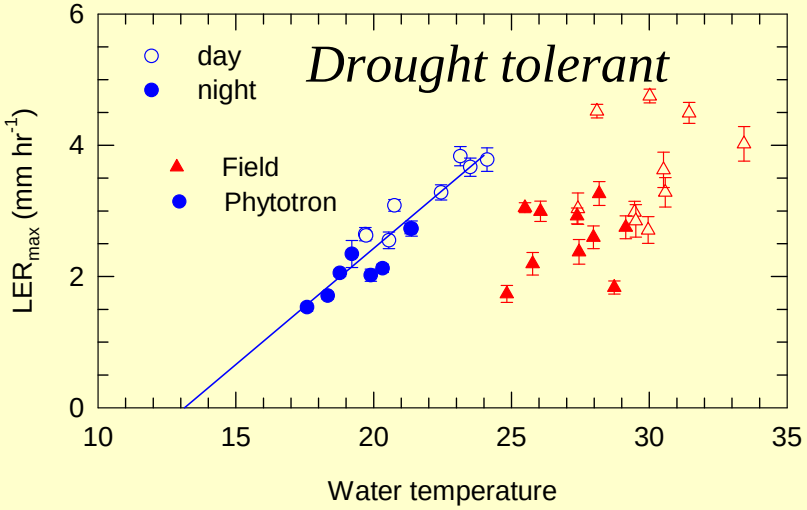
Comparing the temperature response of LER_{max} in the phytotron and in the field

Leaf 9









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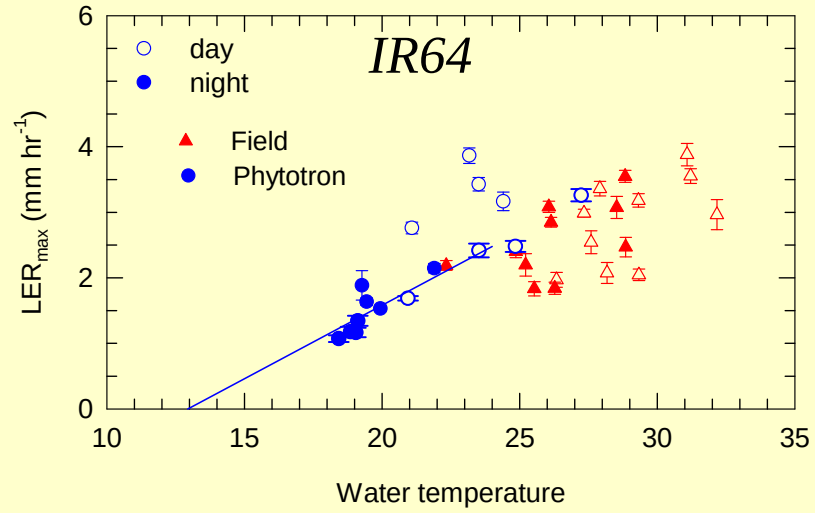
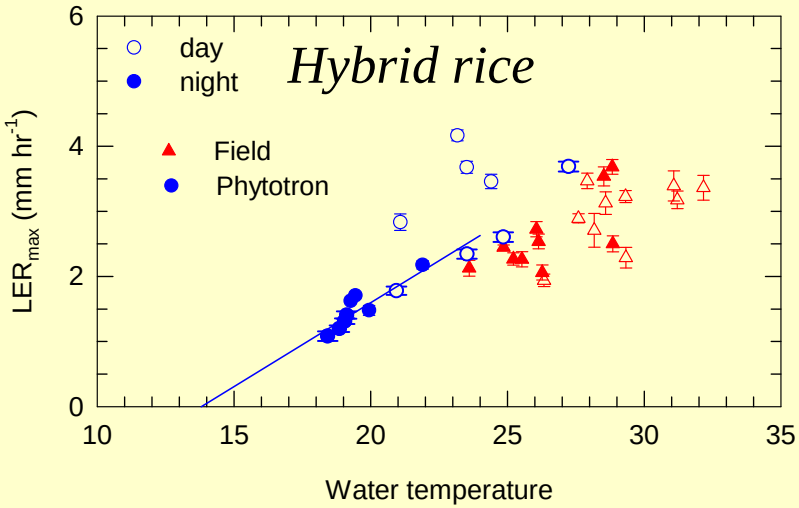
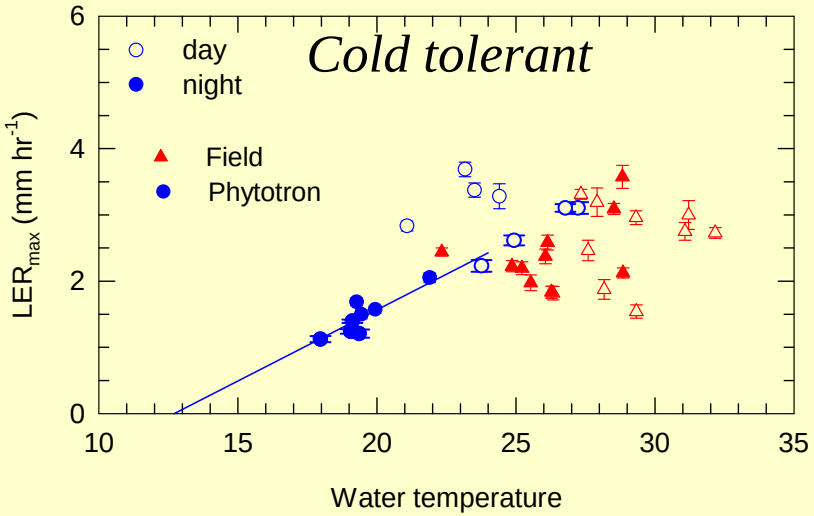
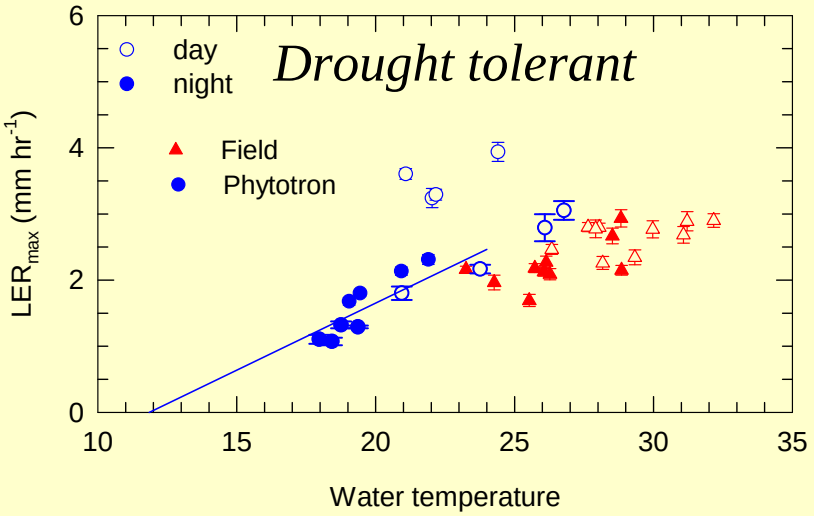
Comparing the temperature response of LER_{max} in the phytotron and in the field

Leaf 6







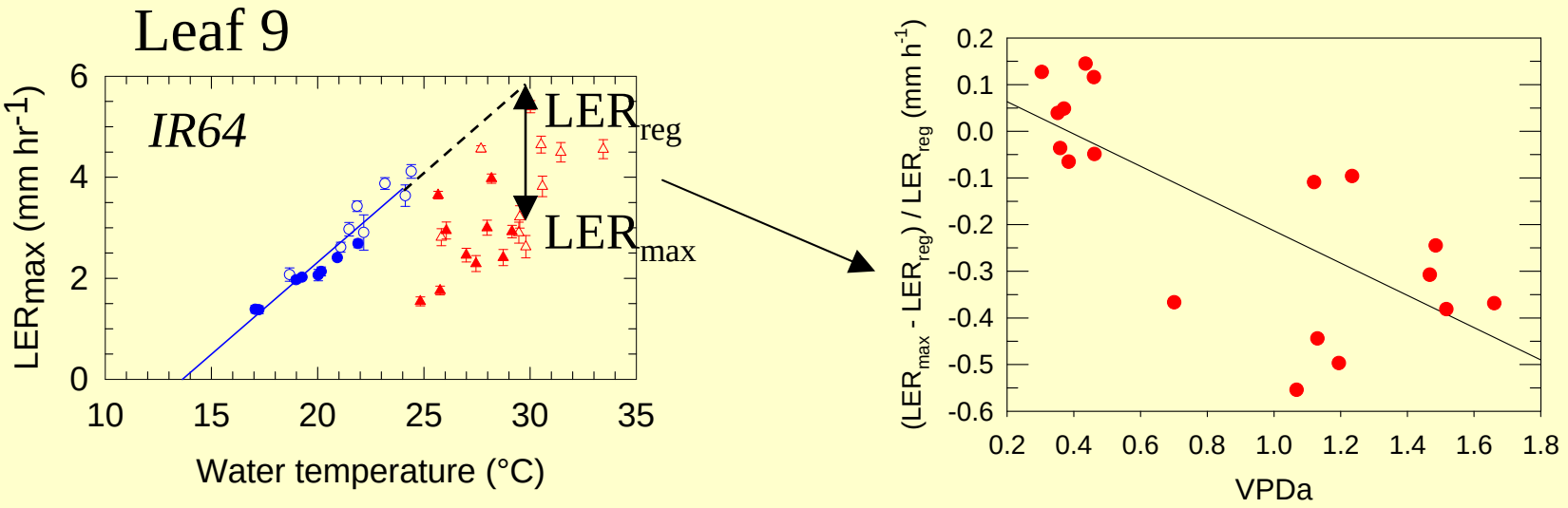


Comparing the temperature response of LER_{max} in the phytotron and in the field

Is there a different response to temperature in field and phytotron?

Is there a contrasted response to night and daytime temperature?

Effect of air VPD on daytime LER_{max}



Higher VPD in the field may explain the reduction in daytime LER_{max}

What about at night?

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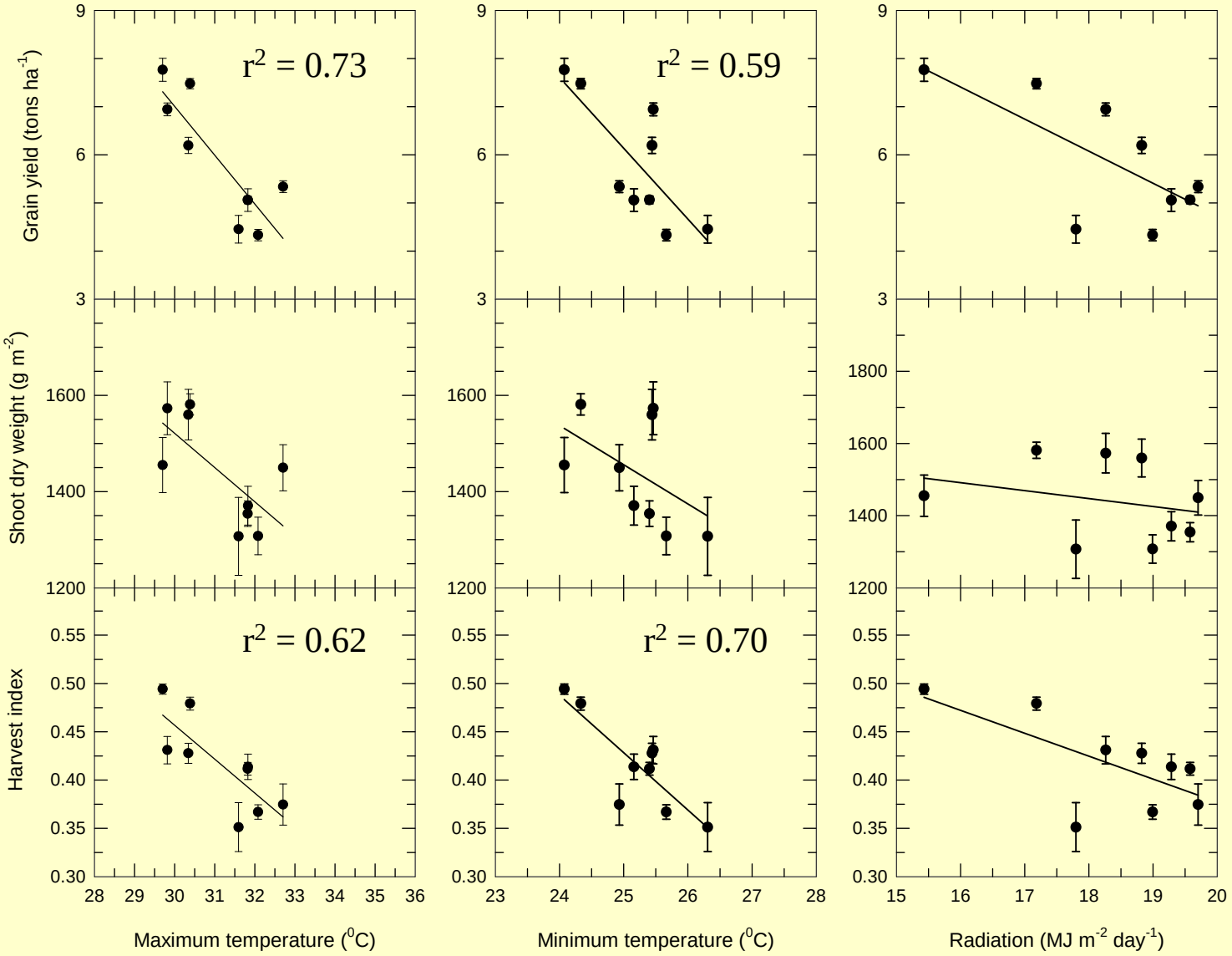
Correlation between grain yield and attributes and climate conditions

IR64, Climate conditions from sowing to maturity



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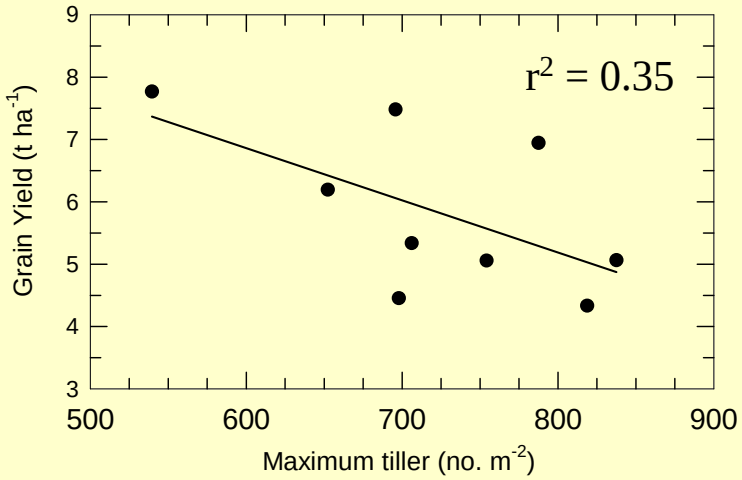
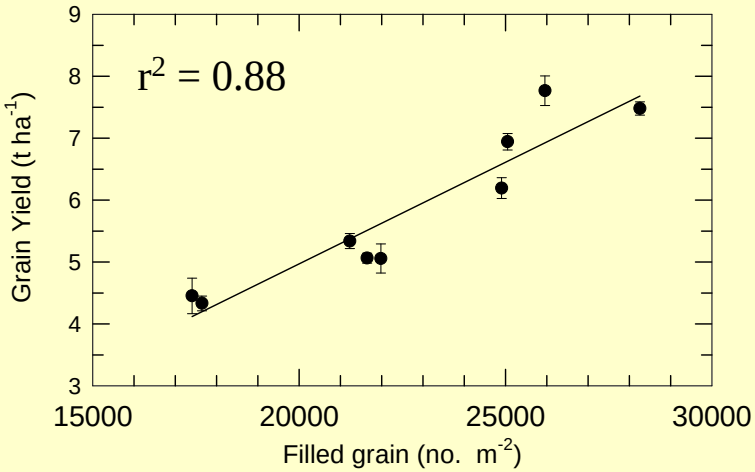
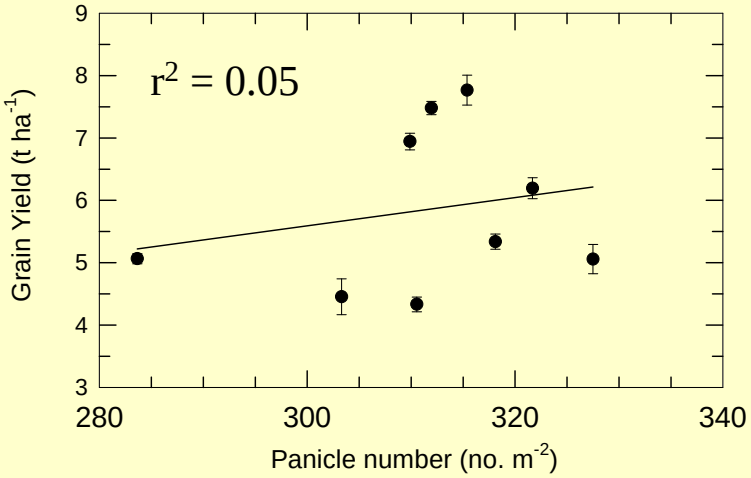
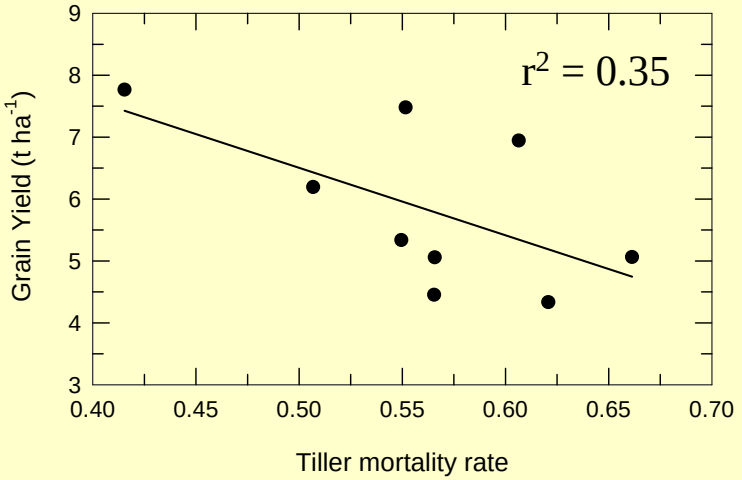
Correlation between grain yield and attributes and climate conditions









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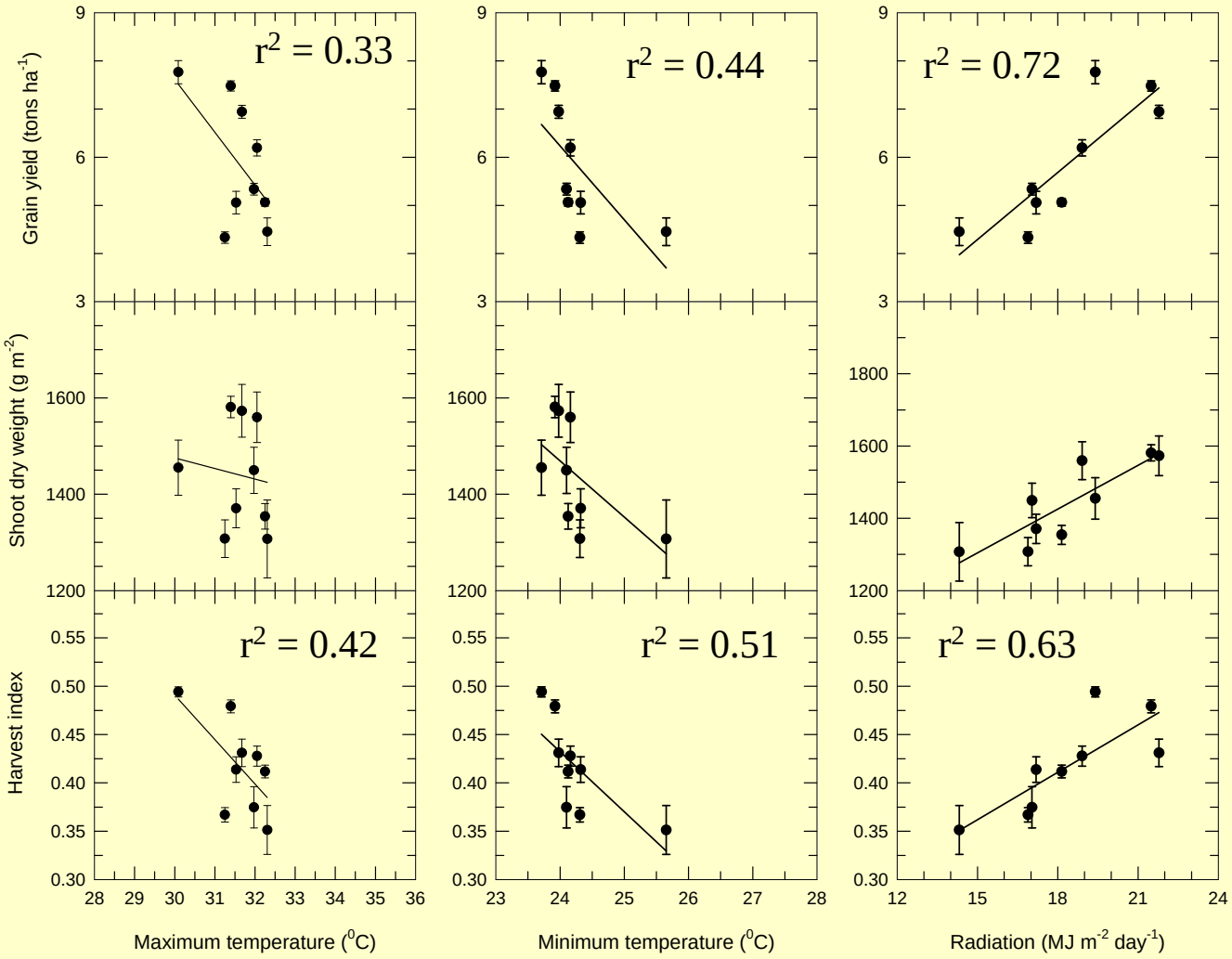
Correlation between grain yield and attributes and climate conditions

IR64, Climate conditions from flowering to maturity



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Conclusions

- In temperature conditions lower than 26C, the effect of day and night temperature on leaf elongation is similar
- In temperature conditions higher than 26C, the response of leaf elongation to daytime temperature appears to be affected by VPD conditions for values as low as 1 kPa
- In temperature conditions higher than 26C, the response of leaf elongation to nighttime temperature is not clear and further data are under collection
- Apparent base temperature varies across genotypes. There is a tendency for lower value for hybrid rice compared to elite lines
- Differential response of day and night temperature on growth processes during grain filling appears to play a key role in determining grain yield

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